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PHYSICAL GEOGRAPHY OF NEW YORK STATE.

BY

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PART IX.—THE SHORE LINES. *

NATURE OF THE COAST LINE.—As one looks at the map of New York, the first thought is that the coast line extends over a very small area; but strictly there is a considerable stretch of shore line, for not only must the entire boundary of Long Island be included (Figs. 13 and 15), together with the coast in the vicinity of New York, but the shores of the Hudson as far as the tide extends; that is about as far up as Troy. Then, also, there is the extended southern coast of Ontario, and a part of Erie, within the State boundaries, besides the shores of many other lakes, large and small.

It is fair to consider the lake and ocean shores together, since, broadly speaking, they are the same in kind and origin. On exposed coasts, as on the outer end of Long Island, the wave action is more powerful than it can be in any lake; but the lake waves in Ontario are more powerful than the ocean waves in protected parts of Long Island Sound; and in many of the small lakes of the State the power of the waves is as great as in the Hudson estuary. In *intensity*, therefore, the wave action in lakes resembles that in ocean bays; but even where the waves are more powerful, as on

* For a general discussion of shore lines see Gilbert, Fifth Annual Report, U. S. Geological Survey, 1885, 69–123; Monograph I, U. S. Geological Survey, 1890, 23–89; Gulliver, Proc. Amer. Acad. Arts and Sciences, XXXIV, 1899, 151–258 (contains an excellent bibliography); Desor, Foster & Whitney's Lake Superior Report, Part II, 1851, pp. 256–270.

exposed ocean coasts, the results produced upon the shore lines differ from those in lakes and bays only in degree, and not in kind.

Besides the greater intensity of open ocean waves, there is also a difference in tidal action. Tides and tidal currents are practically absent from small lakes, and hardly noticeable in the larger ones, such as Ontario;* but in the sea they are very effective agents of change. Another difference between lake and ocean coasts is the life, both plant and animal, which produces marked influence on certain shore lines. Otherwise these coasts are much alike, essentially the same changes being in progress, and the same general results being produced.

EFFECT OF ELEVATION.—Given a sea shore standing at one level for a considerable time, let us examine the results. The waves would gnaw their way through into the land, and the currents deposit the debris off shore, naturally strewing it more or less regularly over the bottom. In time the result would be an off-shore submarine plain, composed of unconsolidated debris. Now, let us assume an uplift which raises a part of this sea-bottom plain into the air—such an uplift, for instance, as might extend the coast of New York and New Jersey forty miles further seaward. This would elevate into the air a level coastal plain traversed by some valleys and dotted with basins, in which water would soon gather; but the boundary

* The tides and other fluctuations in level of the Great Lakes, including the seiches, are described in the following papers: Dearborn, Amer. Journ. Sci., 1829, XVI, 78–94; Whiting, Amer. Journ. Sci., 1831, XX, 205–19; Sharpe, Phil. Mag., 1831, IX, 2nd Ser., 117–19; Mather, Geol. Survey Ohio, 2nd Ann. Rept., 1838, 23–24; Whittlesey, same, 50–53; Dewey, Amer. Journ. Sci., XXXIII, 1838, 403–5; same, XXXVII, 1839, 242–3; Ruggles, Amer. Journ. Sci., XLV, 1843, 18–27; Hall, 4th Dist. Geol. of New York, 1843, 408–410; Dewey, Amer. Journ. Sci., LII, 1846, 85–7; LIII, 1847, 444; Mather, Amer. Journ. Sci., LVI, 1848, 1–20; Foster, Proc. Amer. Acad. Arts and Sciences, II, 1848–52, 131–6; Foster & Whitney, Lake Superior Rept., 1850, 47–53; Whittlesey, Foster & Whitney, Lake Superior Rept., Part II, 1851, 319–339; Amer. Journ. Sci., 1851, LXII, 143–4; Lachlan, Amer. Journ. Sci., 1855, LXIX, 60–71, 164–175; LXX, 1855, 45–53, (From Canadian Journal, July, 1854); Whittlesey, Proc. Amer. Assoc. Adv. of Science, 1857, XI, 154–60; Whittlesey, Amer. Journ. Sci., 1859, LXXVII, 305–310 447; Dewey, same, LXXVII, 1859, 398–399; LXXIX, 1860, 300–301; Graham, Proc. Amer. Assoc. Adv. Sci., 1860, XIV, 52–60; Whittlesey, Proc. Amer. Assoc. Adv. Sci., 1873, XXII, 42–6; Same, XXIII, 1874, 139–143; Dawson, Nature, 1874, IX, 504–506; Schermerhorn, Amer. Journ. Sci., 1887, CXXXIII, 282–284; Drummond, Nature, 1889, XXXIX, 582; Drummond, Nature, 1889, XL, 416; Clark, Trans. Canad. Inst., II, 1890–91, 154–7; Harrington, Nature, XLIX, 1894, 592–3; Blunt, Ann. Rept. Chief of Engineers U. S. Army, 1894, Part 6, 3431–35; Gilbert, Nat. Geog. Mag. 1897, VIII, 238–42.

line, where sea and land meet, would form a rather straight coast line. The conditions illustrated on the Texas coast would in general be reproduced; and, as in the case of the Texas coast, the waves and currents would act upon the soft, unconsolidated clays and sands of the old sea-bottom plain.

No such condition as this is noticed in New York State at the present day; but at the time when the Hudson River reached seaward* to the edge of the continental shelf, the contact of waves and land was at times of this nature; and, farther back in time, when the great Paleozoic sea covered western New York, and the soft shales and sands of late Paleozoic age were being lifted out of the ocean by the Appalachian Mountain uplift, there were doubtless similar conditions in a part of the State now far removed from the sea shore.

EFFECT OF DEPRESSION.— † Grant the same coast with which we started before, but this time assume the land to be depressed instead of the sea-bed to be elevated, and the conditions produced will be found to be very different. Streams have been flowing over this land, so that it has been carved into hills and valleys, and now, as the sea encroaches upon the sinking continent, it enters up the valleys, forming bays, while the hills between them form projecting headlands, capes if small, peninsulas if large (Fig. 1). With continued sinking, the sea reaches over cross valleys, forming islands, with straits behind them; and, if the submergence proceeds still further, some of these lower hill-tops become entirely submerged, forming shoals.

Such a coast, in contrast with one due to elevation, is markedly irregular, the amount and nature of the irregularity varying with the amount of subsidence, the nature of the rocks, and the extent to which the land has been dissected by streams. Thus in the Canadian region, where the submergence has been extensive, and the hard rocks of the country were previously carved by the action of great rivers, not only have innumerable small bays, straits,

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* See No. V of this series, Bull. Amer. Geog. Soc., XXX, 1898, 401–406.

† The literature on submerged coasts is exceedingly extensive, and the following references are to only a few of those which describe the region included in this paper: De Geer, Amer. Geol., XI, 1893, 22–44; De Geer, Proc. Boston Soc. Nat. Hist., 1891–92, XXV, 454–477; De Geer, Amer. Geol., 1892, IX, 247–49; Upham, Bull. Geol. Soc. Amer., I, 1890, 563–67; Upham, Proc. Amer. Assoc. Adv. Sci., 1892, XLI, 171–3; Upham, Bull. Geol. Soc. Amer., III, 1892, 508–11; Cook, Geol. Survey New Jersey, Cape May Report, 1857, 15–65; Cook, Amer. Journ. Sci., 1857, LXXIV, 341–354; Cook, Ann. Rept. Geol. Survey of New Jersey, 1885, 57–70.

capes and islands been produced in marked profusion of variety, but also immense bays, like Hudson Bay and the Bay of St. Lawrence, immense peninsulas, like those of Labrador and Nova Scotia, large islands, such as Cape Breton Island, Newfoundland,

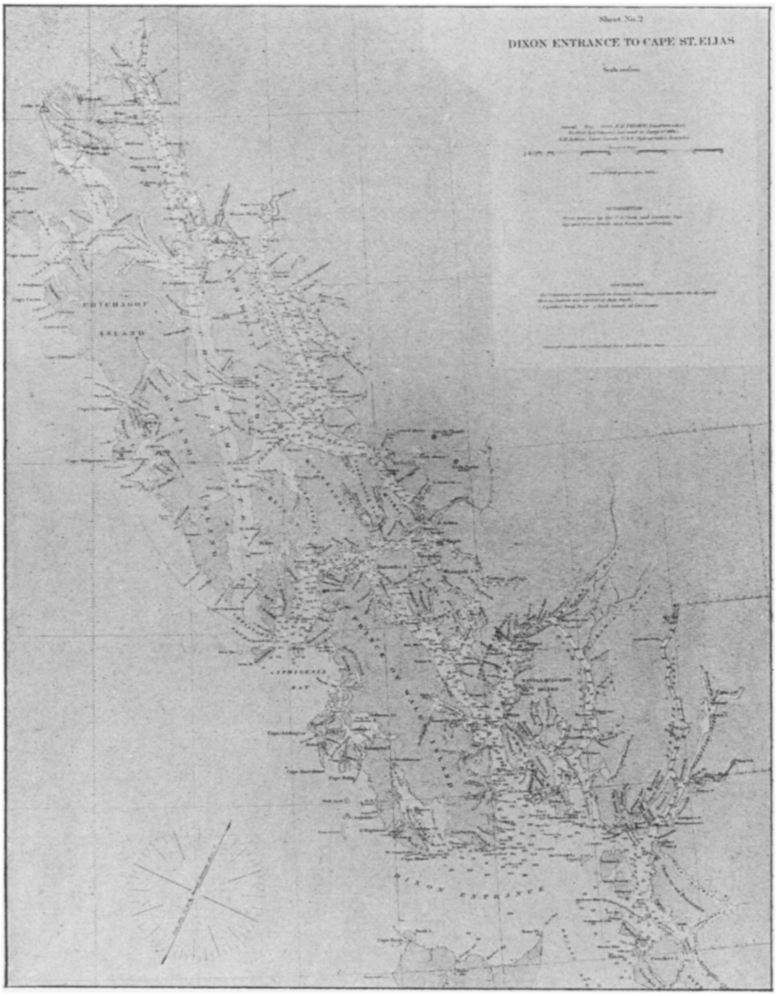

FIG. 1.—A MAP OF THE DROWNED COAST OF A PART OF ALASKA WHERE THE SEA ENTERS FAR INTO THE LAND IN NUMEROUS BRANCHING CHANNELS.

etc., and extensive shoals, completely submerged hills, such as those forming the Fishing Banks. A similar subsidence has produced the irregular coast of the British Isles, and has severed them

by admitting the sea across the divide between two valleys, forming the English Channel.

In like manner the rocky coast of New England, with its innumerable islands and bays (Figs. 2 and 12), and the still more deeply indented fjord coast of Norway, tell of the entrance of the sea into a sculptured land of hard rock. On the other hand, the sinking of a land of softer strata, possessing a more subdued topography,

FIG. 2.—A PHOTOGRAPH FROM MT. DESERT, ON THE MAINE COAST, SHOWING THE NUMEROUS ISLANDS FORMED BY THE DROWNING OF AN IRREGULAR LAND AREA.

produces a coast of irregular form, but of much less ruggedness. Such a coast is well illustrated in Chesapeake Bay and other irregularities of the continent-border south of New York.

The depressed coast of the New York section stands midway between these two extremes, having some characteristics of each. Long Island Sound (Fig. 13) resembles the Chesapeake rather than the fjord type of depressed coast; but the Hudson, where it crosses the hard strata, is a true fjord of great length. The Bay of New York (Fig. 15), the islands near the city, including Long Island itself, and the narrow straits between these, are all the result of the depression of the land. In fact, the site of New York City and its great possibilities are due to this depression, first by forming a harbor, and secondly, by furnishing protected water communication, both eastward along Long Island Sound, and northward along the Hudson, and thence, by other means, westward.

This depression of the coast in the vicinity of New York City seems to be still in progress, both on Long Island and on the New Jersey coast. In the latter section various signs of subsidence have been discovered and discussed by the State Geologist, the conclusion which he has reached being that the present rate of sinking is about two feet a century.*

*Cook, Geol. Survey of New Jersey, Cape May Report, 1857, 15–65; Cook, Amer. Journ. Sci., 1857, LXXIV, 341–354; Cook, Ann. Rept. Geol. Survey of New Jersey, 1885, 57–70.

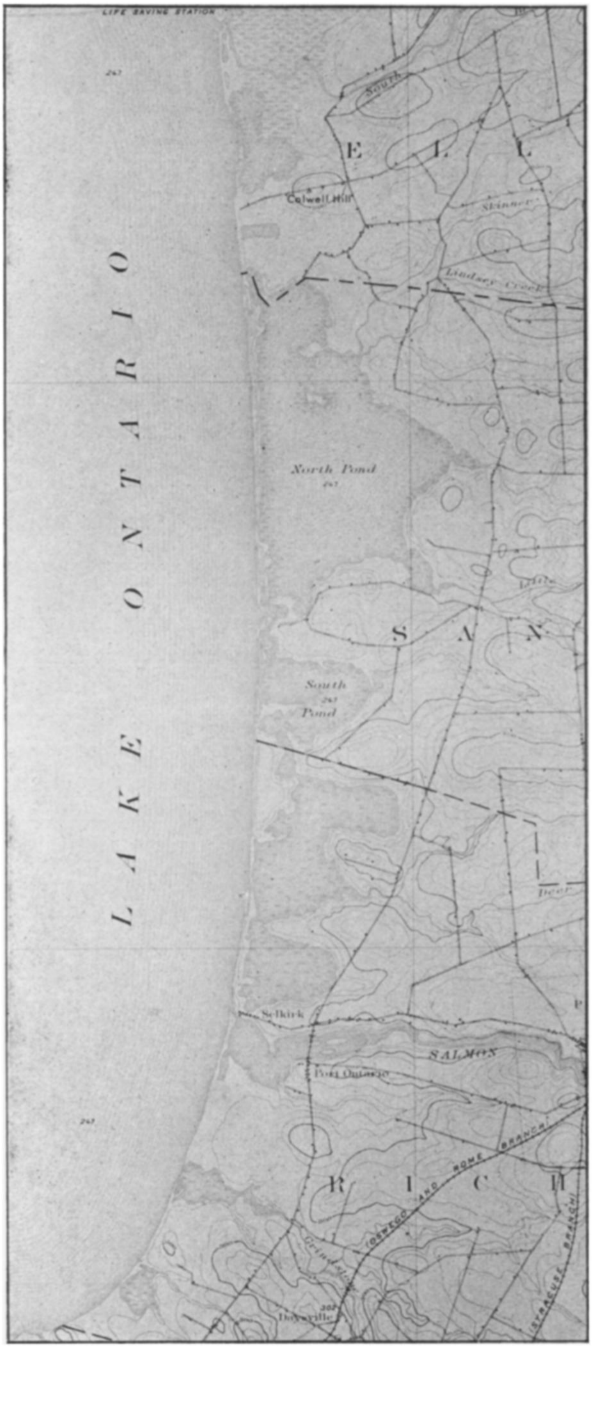

FIG. 3.—A PART OF THE SOUTHERN SHORE OF LAKE ONTARIO WHERE, BECAUSE OF TILTING, THE LAKE WATERS HAVE ENTERED THE VALLEYS, FORMING BAYS, NOW PARTLY ENCLOSED BY THE GROWTH OF BARS ACROSS THEIR ENTRANCES.

The formation of an irregular shore line may be produced in other ways, as by mountain folding or by volcanic action, both of which will cause islands, peninsulas, bays, etc., but neither of which is at present represented within the boundaries of New York. Another cause for irregularity of coast lines is illustrated in Lakes Ontario and Erie.* It has been shown that the land has recently risen in that section, with a greater uplift in the north than in the south. This has acted upon the water of the lakes of the State much as the tipping of a basin of water would act, removing the water from one side and causing it to rise on the opposite side. The tilting of the land has caused an encroachmment of the lake waters upon the southern shore, so that the lower valleys have in some cases been entered by the lake water and transformed to bays (Figs. 3 and 20). An examination of a map of the State will furnish abundant illustrations of bays of this origin along the southern shore of Lake Ontario.

Then, also, the lakes have occupied valleys which originated before the lake water occupied them, usually having been formed by stream erosion and transformed to basins by various causes, in New York State chiefly by drift dams across some part of the stream valley. Many of the linear lakes of New York occupy parts of river valleys, as is especially well illustrated in the case of Lake Champlain (Fig. 4). When the dam was built and water ponded behind it, this naturally entered the side valleys, forming bays, capes, islands and straits, much as the sea water has formed them when the land has subsided. These irregularities, which are so well illustrated in the case of Champlain, are often in part due to the effect of tilting of the land, so that in any individual case it may be difficult to assign to each of these two causes its relative importance. The marked irregularity of the eastern end of Lake Ontario, including the Thousand Islands (Fig. 5), is due to the rise of the lake waters over pre-existing land until they have overflowed across the irregular land area, in this case a low hilly divide; for the Thousand Island outlet is in no sense the preglacial course of a stream of large size.

Destructional Forms.—Having briefly considered the causes for the marked difference between coasts resulting from land movement, we will now proceed to the consideration of some of the minor changes to which a coast of either origin is subject.

* See No. VIII of this series, Bull. Amer. Geographical Soc., XXXI, 1899, 233–235.

FIG. 4.—A PORTION OF LAKE CHAMPLAIN SHOWING THE VERY IRREGULAR COAST DUE TO THE RISE OF THE LAKE WATERS IN A PREVIOUSLY FORMED VALLEY.

Waves are the most potent of the aqueous forces which are working toward the modification of the coast lines. Beating incessantly against some parts of the shore, they find two tasks to perform—one to grind off fragments, the other to dispose of them. In places where the materials obtained by the waves, whether by their own action or supplied by other causes, can be removed, either by wave or current action, the shore line is attacked and cut back, producing certain forms which may be classed as destructional forms.

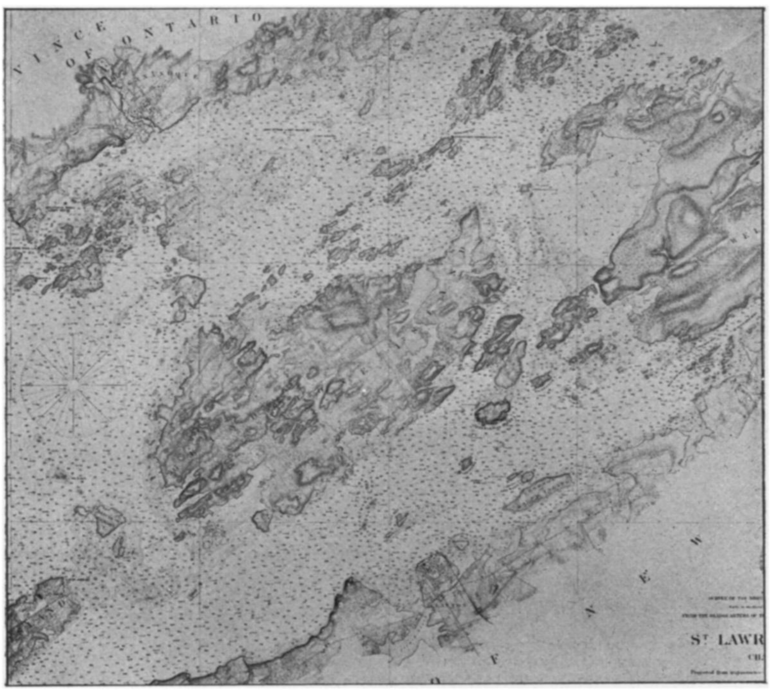

FIG. 5.—MAP OF A PORTION OF THE THOUSAND ISLANDS WHERE THE WATERS OF LAKE ONTARIO RISE OVER A LOW, HILLY LAND SURFACE, SUBMERGING A PART AND TRANSFORMING THE HIGHER PORTIONS INTO ISLANDS AND PENINSULAS.

The attack of the waves upon such a coast line varies in intensity primarily with the force of the waves and the hardness of the rock, being most rapid, other things being equal, where the rock is soft and the wave action vigorous.

Where the strata are soluble, as along limestone coasts, solution is a factor, and in many rocks the disintegration of the minerals is hastened by the salt of the spray and the other impurities from the

sea. Aside from this action, the waves are often able to wrest off fragments by their direct blow, as the result of the compression of air in cavities and the tremendous hydraulic pressure produced by the wave blows. By means of the materials obtained by this action, together with the supply furnished from the land by weathering, by wind and by rivers, the waves are supplied with effective tools, by which they can batter the rocks of the coast and wear them back. It is mainly by this means, rather than by solution or other action, that the coasts are worn back into the land; and among

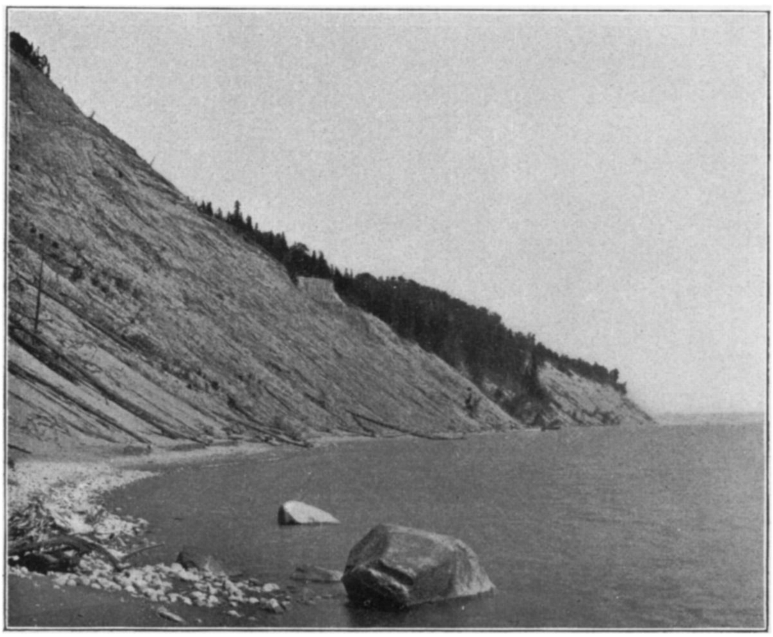

FIG. 6.—A WAVE-CUT CLIFF IN UNCONSOLIDATED STRATA ON THE SHORE OF LAKE MICHIGAN. THAT THIS CLIFF IS BEING CUT BACK AT THE PRESENT TIME IS PROVED BY THE ABSENCE OF VEGETATION ON ITS FACE AND BY THE VERY NARROW BEACH AT ITS BASE.

the factors involved, the most important is the mechanical action of waves, furnished with rock fragments.

The battering ram of wave action is concentrated along a moderately narrow zone, its width varying with the height of the waves; but even in this zone there is a still smaller belt of maximum wave attack, and along this they saw into the rocks with a rapidity in many places sufficient to be noticeable in a single lifetime. This zone of maximum wave action swings up and down with the tides, and this swing constitutes one of the differences between lake and

sea shores; but even in lakes, the fluctuations in level due to seiches and other causes (p. 418) produce a certain swing in the zone of maximum wave attack.

Where the waves are eating into soft, unconsolidated strata, the removal of materials from the zone of wave action undermines those layers that are above it, causing a succession of slides and slips, and producing a cliff with the slope which such materials naturally assume in the air (Fig. 6). With a continuation of these attacks such a cliff is cut further and further back into the land, always maintaining a steep slope, and, in general, free from plant cover so long as the waves are able to remove the supply which they gain. From these bare slopes much rock material is washed into the water

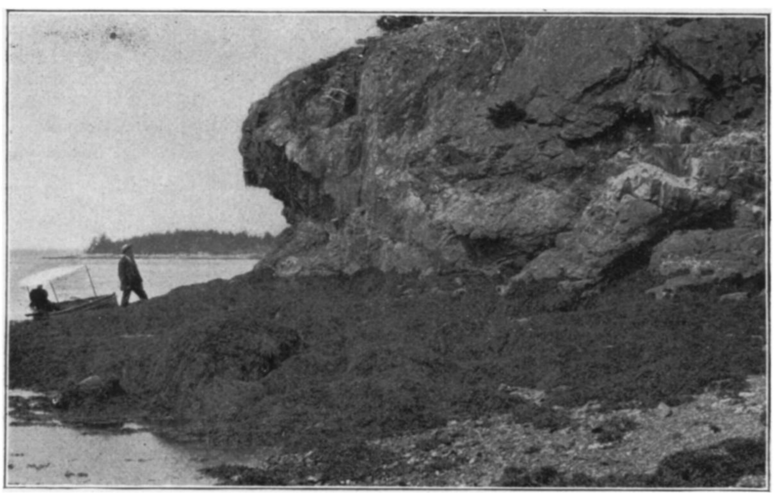

FIG. 7.—A WAVE-CUT ROCK CLIFF AT CASTINE, MAINE, OVERHANGING ABOVE THE ZONE OF MOST ACTIVE WAVE ATTACK.

by the rain and rills, adding to the burden of the waves. Such wave-cut cliffs of clay, sand and gravel are frequently found along the shores of the Great Lakes and also in exposed places on the shores of the smaller lakes.

Much the same result occurs where the waves beat against hard rocks; but here the resistance of these more durable layers often permits the waves to undercut the cliffs, forming sea caves (Fig. 7). More commonly, however, the rock cliffs are nearly vertical, with a slight inclination from base to summit, owing to the greater effect of weathering in the upper portions of the cliff. Such rock cliffs abound along the Erie and Ontario shores in New York, where they have been cut into nearly horizontal strata (Fig. 8). Weathering

and wave attack have often etched out the layers, causing the harder ones to stand out in horizontal sheets beyond the general cliff face. Joints in the rocks render them more open to wave attack, and their effect is often seen in the cliff form, which is frequently made up of a series of angles and smooth joint faces (Fig. 9). Where strata are inclined, much variety in coast form is produced by the nature of the inclination and the variation in the hardness of the strata.

In localities where the rocks vary in hardness from place to place alongshore, the waves often etch out these differences,

FIG. 8.—A WAVE-CUT CLIFF OF SHALE, FACED BY A NARROW PEBBLE BEACH, AT WESTFIELD, N. Y., ON THE ERIE SHORE.

producing chasms and tiny bays in places where the rocks are softer. One often sees such wave-formed irregularities along the rocky New England coast. Numerous joints in a certain zone also give rise to indentations of this nature, as is frequently illustrated in the shale cliffs of the Erie shore; but such wave-cut bays are, of necessity, minor shore features, because, as soon as a bay of slight depth is cut, the waves are worn out by friction along its sides, thus losing force and hence ability to cut further. No real large bays can be wave-formed.

Under favorable conditions waves are able to cut back on the two sides of a tiny promontory, and then, aided by weathering, to cut behind the end of this, leaving it as an island, or *stack*, entirely removed from the mainland (Fig. 11). The protected sea-coast line

of New York is unfavorable to the formation of such destructional features as this, and, for the most part, furnishes illustration of the opposite type of coast line, that due to processes of construction.

FIG. 9.—JOINTED FACES OF A WAVE-CUT SHALE CLIFF ON THE SHORES OF LAKE CAYUGA, N. Y. THE COAST HAS BEEN SLIGHTLY MODIFIED BY THE BUILDING OF A RAILWAY ON THE BEACH AT THE BASE OF THE CLIFF.

CONSTRUCTIONAL FORMS.—The materials furnished to the waves and wrested by them from the coast cannot always be at once removed. Some of them accumulate at the base of the cliffs, or in

FIG. 10.—A TINY POCKET BEACH ON THE SHORES OF LAKE SUPERIOR, WHERE THE PEBBLES WRESTED FROM THE CLIFFS HAVE BEEN DRIVEN INTO A PROTECTED ANGLE IN THE COAST.

the minor indentations of the shore line, forming beaches (Fig. 10). These become mills in which the waves are able to grind the rock fragments to such a size that they are more easily removed. All along the coast line, both of the lakes and of the sea, there are beaches of this kind, some of them pebbly, others sandy. There is a considerable variation in the form of the beaches under varying circumstances.

The simplest beach is that made of fragments from the nearby cliffs. Upon this the waves break, rolling the rock fragments to and fro and grinding them finer. By the aid of the undertow much of this ground-up material is removed and distributed over the bottom, off shore, levelling the lake or sea-bed; but much is also disposed of by being driven alongshore, for, when a wave breaks against the cliff or beach, unless it approaches *directly* upon the coast, its attack is diagonal to the trend of the shore, and with each breaking wave the fragments are pushed along the shore in front of the wave. When watching the breaking wave one is often able to see this movement of the pebbles; and it is equally well proved by studying the transportation of rock fragments, of some kind that can be easily identified, in the direction of maximum wave movement.

Added to these two causes for the transportation of wave-derived materials, is the current-like movement of the water itself, which the wind produces; for, when the wind blows diagonally against or parallel to the coast, a surface drift of water is produced, which moves alongshore in either one of the two directions, according to the wind direction. This wind-formed current tends to drift fragments in the same direction that the breaking waves push them, and is, therefore, a support to wave action; but it must be considered of less importance than wave action, because it is never powerful enough to move any excepting the smaller fragments, while the breaking wave will transport good-sized pebbles, and even boulders.

Since on every coast there is one direction from which the *average* wind-formed waves strike with greater force and persistence than from other directions, there is, of necessity, one direction in which the rock fragments are prevailingly moved. For instance, on the shores of Lakes Erie and Ontario, the winds from the western quadrant are more frequent than those from the eastern, and so the rock fragments are moved farther toward the east than toward the west.* On Long Island, on the other hand, the west winds, blowing

*Dewey, Amer. Journ. Sci., LII, 1846, 85–7; LIII, 1847, 444; Clark, Trans. Canad. Inst. II, 1890–91, 154–7; Harrington, Nature, XLIX, 1894, 592–3; and other articles referred to on p. 418.

from the land, are much less effective than the east winds from the ocean, and the movement of particles is therefore from the east (Fig. 13).

While we have considered only the movements resulting from wind and wave, it must not be overlooked that on the sea shore these causes for the movement of particles are sometimes aided, sometimes checked, or seriously modified, by the action of the tide. In some places tidal currents are so powerful that they furnish the dominant force in determining the coastal form. This is all the more liable to be true where the tidal currents are powerful, because such currents are, as a rule, much less well developed upon exposed coasts than they are in the inclosed bays, where wave action itself is normally weak and hence easily counterbalanced by even moderate tidal currents.

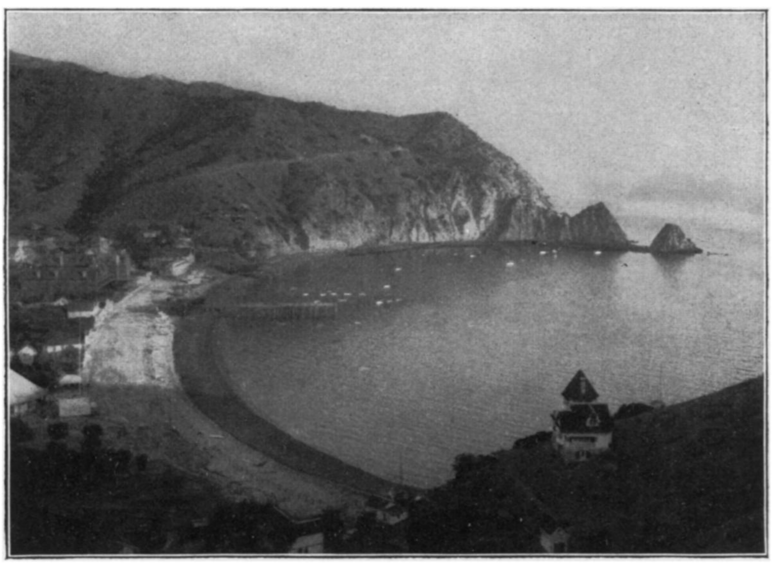

FIG. 11.—THE HARBOR OF AVALON ON CATALINA ISLAND, CALIFORNIA, SHOWING A BEAUTIFUL CRESCENT BEACH AT THE HEAD OF A BAY INTO WHICH FRAGMENTS DERIVED FROM THE HEADLANDS ARE DRIVEN.

The effect upon the coast form of these various causes for removal of wave-derived materials is very pronounced. Rock fragments from cliffs are often driven into little bays, where, in their protected position, they form pocket beaches (Figs. 10 and 11). Or, where the coast is more irregular, fragments may be driven from the exposed outer edges of an island around its margin to the protected rear, where, being out of reach of the waves, they form bars, which

grow until, finally, the island is connected either to another island or else to the mainland (Fig. 12). These tied islands are sometimes connected with the mainland by a single bar; at other times by a double one.

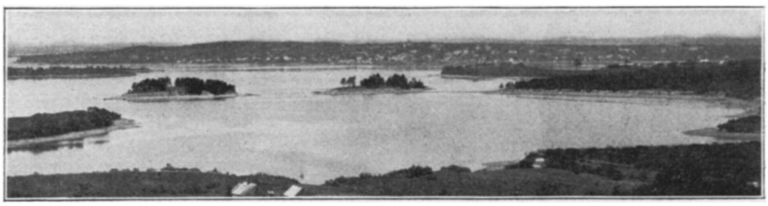

FIG. 12.—THE DROWNED COAST OF MAINE, SHOWING A PART OF CASTINE HARBOR, WITH PENINSULAS AND ISLANDS, ONE OF THE LATTER BEING TIED TO THE MAINLAND BY A BAR BUILT IN THE LEE OF THE ISLAND.

In other cases, where the coast is indented by bays, the driving of the particles alongshore oftentimes builds a bar from the margin of the bay out across the indentation (Figs. 13 and 20). Such growing bars will be found on most irregular coasts, sometimes so poorly developed that they would not be noticed, excepting upon a carefully constructed contour map; or, in other places, forming pronounced shoals, dangerous to navigation and requiring the location of buoys and even lights to mark their dangerous location. When still further developed, these bars are well above the water, either partly, or, in cases, completely inclosing the bay. Along the southern shore of Long Island excellent illustrations of various stages of this bay-closing are found (Fig. 13).* The long bar of Fire Island beach is an excellent illustration of this, the fragments from which it is made having been derived by the waves from eastern Long Island and driven westward by the winds and waves, perhaps aided by tidal currents.

In the construction of such bars as this the waves, first of all, drive the fragments along and heap them up to the height which the higher waves reach. This makes a bar in the sea, whose surface is exposed to the air under ordinary conditions of weather, being reached by the waves only when the heaviest storms prevail. During this interval of exposure to the air, the finer fragments of sand are dried and brought under the influence of the winds, which drift them about, broadening the bar and raising its surface higher, until finally, habitable land is made in the sea (Fig. 14). By this

* Rogers, Rept. Brit. Assoc., 1834, IV, 11 ; Mather, First Rept. Geol. of New York, 1837, 76–84 ; Second Rept., Same, 1838, 125–133 ; Mather, Geology of New York, 1st Dist., 17–33 ; 234–235.

FIG. 13.—THE LONG ISLAND COAST, SHOWING THE LONG FIRE ISLAND BAR REACHING WESTWARD AND REPLACING THE IRREGULAR COAST BY A STRAIGHT BEACH.

combined action of waves and wind, which piles the sand into narrow strips, a vast amount of land has been made that is of use for purposes of summer resort and for the homes of fishermen. The surface of these wind- and wave-constructed bars is usually made of loose sand, irregular in form and frequently changing in outline under the influence of the variable winds. Sand-dunes, like these in out-

FIG. 14.—THE SURFACE OF THE BAR OF MONOMOY ISLAND ON THE MASSACHUSETTS COAST, A BAR BUILT UP BY WAVES AND WIND, THE LATTER STILL SHIFTING THE SAND ABOUT.

line, are not confined to the bars that have been built *in* the sea. They are also found bordering the coast, as, for instance, on the sandy shore of Long Island.*

Sandy Hook (Figs. 15, 16 and 17) furnishes another illustration similar to the Fire Island beach. On the New Jersey coast the effective wave-forming winds blow from the southeast and northeast,† and the materials which these waves derive are drifted along the coast, northward by the southerly winds, and southward by the northerly winds. Owing to the predominance, or rather to the greater effectiveness of the northeast winds, the best bar is that developed south of Ocean Grove in the direction of Barnegat ;

* Mather, Geology of New York, 1st Dist., 30–32 ; 233–4.

† Bache, Proc. Amer. Assoc. Adv. Sci., X, 1856, 171–2 ; Bache, Amer. Journ. Sci., 1857, LXXIII, 16–17 ; Bache, Proc. Amer. Assoc. Adv. Sci., 1858, XII, 80–92; Bache, Amer. Journ. Sci., 1858, LXXVI, 334–342; Appendix 27, U. S. Coast Survey Report, 1858, 197–203 ; Mitchell, Science, IX, 1887, 204–5 ; Cook, Ann. Rept. New Jersey Geol. Survey, 1882, 80–83 ; Cook, Ann. Rept. New Jersey Geol. Survey, 1885, 57–96 ; Davis, Proc. Amer. Acad. Arts and Sciences, XXXI, 1896, 303–332 ; Gulliver, Proc. Amer. Acad. Arts and Sciences, XXXIV, 1899, 151–258. For reference to a number of other papers on New York harbor and vicinity, many published in U. S. Coast Survey Reports, see Nat. Acad. of Science Biographical Sketches, vol. I, 1877, pp. 205–212 (bibliography of A. D. Bache).

FIG. 15.—A RELIEF MAP OF NEW JERSEY SHOWING THE DROWNED COAST NEAR NEW YORK, THE CLIFFS SOUTH OF NEW YORK, THE BARS FORMED BY THE WAVES, THE SALT MARSHES BEHIND THEM AND THE CLIFFS OF THE OLD LAND BEHIND THESE. (NEW JERSEY GEOL. SURVEY MAP.)

but an excellent bar is also developed on the northern end, forming Sandy Hook. Here the winds from the northeast cannot produce a great effect, because of the protection furnished by the land to the north of the Sandy Hook region; but the waves and winds from the southeast, having a much larger stretch of water to blow over, *are* effective, and the sand has been driven along before them. Doubtless, tidal currents have had some influence in determining the form of Sandy Hook, especially in influencing its

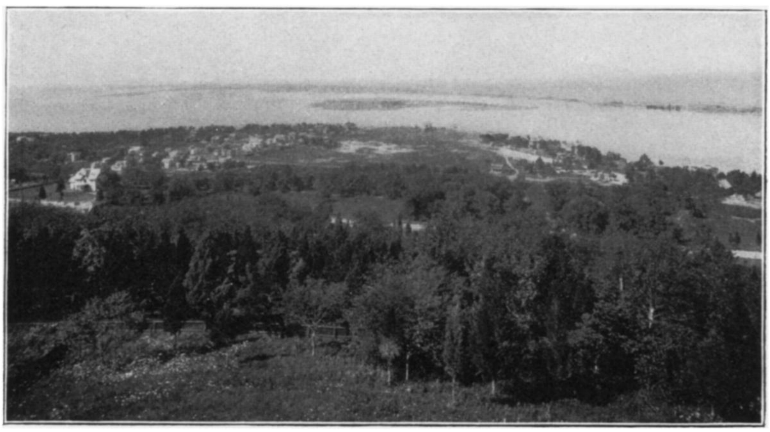

FIG. 16.—VIEW OF SANDY HOOK FROM NAVESINK HIGHLANDS SHOWING THE BAR PROTECTING THE OLD SEA CLIFF, FROM WHICH THE PICTURE WAS TAKEN.

westward turn, although probably the principal cause for this is the power of the east wind, which has turned the end of the bar landward.

Before Sandy Hook had been built out to its present position in front of the Navesink Highlands, the ocean waves beat directly upon the New Jersey coast and cut the cliff which faces the seaward side of this highland (Figs. 15 and 17). With the constant supply of material from the cliffs to the south, driven alongshore by winds, waves and tides, the bar has reached further and further northward, until it has so compassed the Navesink region as to protect the cliffs from further attack by the waves. In geographic nomenclature such a growth of land in the sea as is represented by the Sandy Hook and Fire Island bars, forms the *new land*, in contradistinction to the *old land*, of which Navesink Highlands may be taken as a type. Through the action of the waves and winds, in a manner similar to that which has been briefly sketched here, a vast amount of new land has been built, in the form of off-shore bars, from New York City southward to the Rio Grande.

FIG. 17.—THE BAR OF SANDY HOOK STRETCHING FROM THE CLIFFS SOUTH OF LONG BRANCH PAST THE BAYS OF THE DROWNED COAST AND IN FRONT OF THE SEA CLIFFS OF NAVESINK HIGHLANDS.

There are, besides these that have been mentioned, numerous other forms assumed by bars. In some places, for instance, a spit

FIG. 18.—CROW BAR POINT, A SPIT BUILT OUT FROM THE SHORES OF LAKE CAYUGA, N. Y., AT A BEND IN THE LAKE.

grows directly out from the land * where, at a turn in the lake, the opposing winds drive fragments before them, and in the conflict of forces, build the bar outward (Fig. 18). Elsewhere the spit is curved

FIG. 19.—A HOOKED BAR, FORMED BY THE WAVES MODIFYING A DELTA ON THE ERIE SHORE AT SILVER CREEK, N. Y.

at the end, forming a hook. Then, also, there are V-shaped bars with the angle of the V projecting outward, and called cuspate forelands.*

* Tarr, Amer. Geologist, XXII, 1898, 1–12.

* Abbe, Proc. Boston Soc. Nat. History, XXVI, 1895, 489–497; Gulliver, Bull. Geol. Soc. Amer., VII, 1895–96, 399–422; Gulliver, Geog. Journ., 1897, IX, 536–546; Gulliver, Proc. Amer. Society Arts and Science, XXXIV, 1899, 151–258; Tarr, Amer. Geol., XXII, 1898, 1–12.

Small ones occur on many coasts, and larger ones are represented by Capes Hatteras, Canaveral and Fear. Deltas opposite the mouths of streams which enter lakes or bays along the sea coast, are often modified by waves and currents until they lose their symmetry of form, and, at least in part, become bars (Fig. 19). In an article limited as this is, it would be impossible to present a complete analysis of the wave work and bar construction, so that no attempt will be made to explain the variations from the normal represented by Hatteras and other cuspate forelands and by some of the other forms of bars.

STRAIGHTENING OF THE COAST.—The effect of the growth of bars along an irregular coast is to straighten it, as one may readily

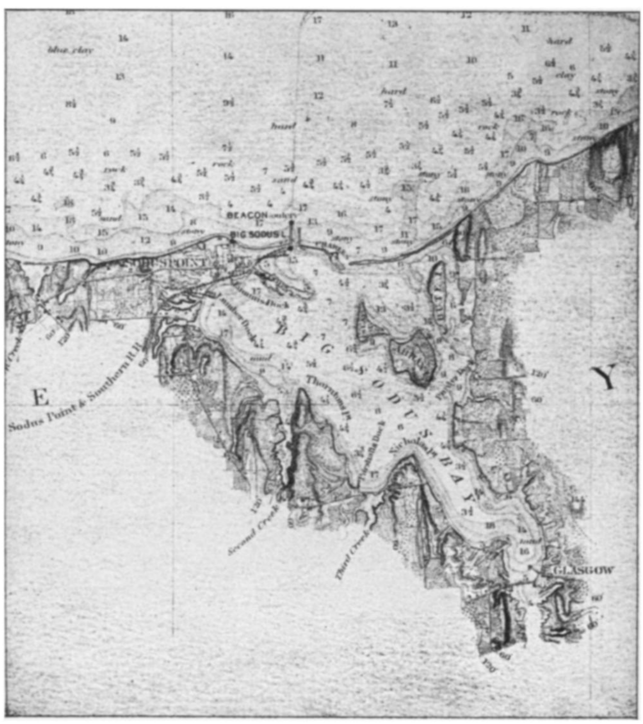

FIG. 20.—BARS ENCLOSING THE BIG SODUS BAY ON THE ONTARIO SHORE.

see by examining a map of the Long Island or New Jersey shores (Figs. 13, 15, 17 and 20). The headlands are cut back, bars are built across the mouths of bays, and the bays themselves are frequently filled and obliterated by the supply of material brought

into them by streams from the land, by wind, by waves and by tides. Sediment from the land has been dumped behind the bars of the New Jersey and Long Island coasts, and they have become gradually filled, so that, in some places, at low tide, there is direct communication between the off-shore bar and the old land. Upon the sandy and muddy bottoms of inclosed bays which are being filled by incoming sediment, marsh grass takes root and aids in the completion of the process of transforming the bay to a level, swampy plain (Figs. 15 and 21). This is at first traversed by numerous channel-

FIG. 21.—A SALT MARSH FORMING BEHIND A SAND BAR AT BOURNE ON THE MASSACHUSETTS COAST.

ways and covered by the high tide; but ultimately it is transformed to a level plain, which is only reached by the very highest tides of the year, and, later, is gradually built beyond the reach even of these.*

These salt marshes, when they have reached well along toward completion, are well adapted to use as farming land, if only the salt water can be excluded. Owing to the cheapness of farming land in this country, little has been done to utilize the vast resources of salt marsh, much of which is located within easy reach of some of the large cities. There are vast tracts of such land which might readily be reclaimed within a few miles of New York City and hundreds of thousands of acres at other places along the sea coast. While little has been done in this section, other parts of the world furnish ex-

* Mather, Geology of New York, 17–19, 234; Cook, Geol. Survey New Jersey, Cape May Report, 1857, 15–65, 91–94; Cook, Ann. Rept. New Jersey Geol. Survey, 1869, 23–41; Cook, Geology of New Jersey, 1869, 300–308; Cook, Ann. Rept. New Jersey Geol Survey, 1885, 61–70; Smock, Ann. Rept. New Jersey Geol. Survey, 1892, 313–353; Vermeule, Ann. Rept. New Jersey Geol. Survey, 1896, 289–317; Shaler, Sixth Ann. Rept. U. S. Geol. Survey, 1885, 353–398.

cellent illustration of the possibility of reclaiming this land from the sea. On our own continent, the largest areas are those in the Bay of Fundy (Fig. 22) (the land of Evangeline), which were reclaimed by the Acadians, and which now form some of the best farming land in the eastern provinces. In Europe a great deal of salt marsh has been reclaimed in England, Belgium, Holland and elsewhere. In Holland the reclamation has gone so far as to extend beyond the zone of marsh grass growth and include the muddy bay floor; the reclamation of the salt swamps of New Jersey will be accomplished

FIG. 22.—A DIKE FOR RECLAIMING SALT MARSH IN THE BAY OF FUNDY.

in the future. Excellent descriptions of the New Jersey marshes and the possibilities of their reclamation will be found in the reports referred to below.*

If the land were to remain long enough at the present level the Hudson estuary would become partly filled, much as some of the shallow bays have already been, and the water area would be narrowed and the depth decreased. In fact New York Bay would also become transformed to a plain traversed by a few channels for conducting off the fresh water from the land, while even Long Island Sound itself would finally suffer the same fate. Doubtless before such fate shall have come, the rising or sinking of the land will have changed the conditions of the coast line so completely that its effect will not be noticeable; but even within historic times the

* Cook, Geol. Survey New Jersey, Cape May Report, 1857, 15–65, 91–94; Cook, Ann. Rept. New Jersey Geol. Survey, 1869, 23–41; Cook, Geology of New Jersey, 1869, 300–308; Cook, Ann. Rept. New Jersey Geol. Survey, 1885, 61–70; Vermeule Ann. Rept. New Jersey Geol. Survey, 1896, 289–317; Shaler, Sixth Ann. Rept. U. S. Geol. Survey, 1885, 353–98.

measurements of the breadth and depth of bays have shown that they are in process of filling, as a geologist would have decided, with equal certainty, on the basis of the geological fact that materials are entering them in excess of the ability of the oceanic agents to remove. This work of filling is so rapid that in many harbors constant effort is necessary to prevent the encroachment of land upon the sea and to maintain the harbor in good condition. How much the filling amounts to in the case of individual bays along the lake and sea shore of New York, it is too early to state, for careful measurements have not been made through a long enough period of time to determine this; nor are we able to say whether the movement of the land, which is *apparently* in progress, and which is estimated on the New York shore to represent a sinking at the rate of about two feet a century, will be sufficiently great to overcome the process of filling, which is *certainly* in progress.

Elsewhere in the world other forms of life than the marsh grasses aid in the production of land in the sea. It will not be possible to enter into a consideration of these in detail, but merely to mention them. The most important plants are the trees, called mangroves, which grow in tropical lands, producing swamps, much as the marsh grass of the northern States causes swamps in the inclosed areas. In this country we have tree-covered mangrove swamps on the Florida peninsula, and they are abundant along many other tropical coasts, the tree-covered swamp predominating in tropical regions, treeless marshes in temperate latitudes, and both being absent from the Arctic. During the coal period there were doubtless tree-covered swamps in southern New York, as there were in Pennsylvania, though now, by erosion, even the beds of coal which they formed have been removed.

Many animals are engaged in the work of land-making, but none are so noteworthy as the corals, which, aided by other lime-secreting animals, have made so many reefs and islands in the sea. The southern end of Florida and the Keys south of that peninsula, as well as the Bermuda and Bahama Islands, and the borders of some of the West Indian islands, notably Cuba and Porto Rico, are illustrations of the work of animal life in land construction. Here, as in the case of bars, the work of waves in raising the fragments into the air, and of winds in blowing them still higher, are important features in the construction of land, for the animals themselves, which secrete the material, are able to grow only beneath the water surface. Since none of these forms of life are represented in New York, no further discussion of them seems called for here.

ELEVATED SHORE LINES.—As has been shown in previous articles of this series,* there are, in various parts of New York State, evidences of former higher levels of lakes, particularly along the shores of the Great Lakes. These are in the form of well-defined deltas, beaches, bars and some wave-cut cliffs. They were formed during higher levels of the lakes and now stand as the principal witnesses of these former higher levels.

Also shore lines of marine origin are found in the St. Lawrence valley and in the Champlain-Hudson depression. Those in the Hudson valley are not in the form of well-defined beaches; but distinct beaches are found in the St. Lawrence and Champlain valleys, and the discovery of marine fossils in them proves that they were formed below sea-level. Since the depression in the north was greater than in the south, the ocean shore lines reach higher levels in the northern than in the southern parts of New York. This is true along the Hudson,† where the elevation of the marine deposits at Albany is 340 feet and near New York 80 feet. While it cannot be considered as positively proved that all of the terrace deposits along the Hudson are marine, or rather estuarine, in origin, the work so far done upon them points towards this conclusion: that, in some cases, as for instance, the deltas from the Catskill to Albany, the origin is estuarine.

Far back in geological time there have been other periods when shore lines within the boundaries of the State have been elevated above the level of the sea. The conglomerates of the Catskill Mountains, for instance, represent beaches of Devonian age, and there are still others preserved among the Silurian and Devonian rocks. Indeed, even before this, near the beginning of the Paleozoic, the sea carved cliffs along the flanks of the Adirondacks and built beaches from the pebbles thus wrested from the land. This is proved by the fossil beaches preserved among the consolidated strata of Cambrian age.

These elevated beaches furnish proof of the instability of the land and make it still more easy to understand the changes which have brought about the irregularities due to land-sinking mentioned earlier in the article, and to believe in the possibility of still further changes in the future, which may so modify the coast near the City of New York as to greatly modify its political and commercial importance.

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* Bull. Amer. Geog. Soc., 1899, XXXI, 217–235.

† See References in Part V of this series, Bull. Amer. Geog. Soc., XXX, 1898, 405, and in Part VIII, XXXI, 1899, 227.